or moon in bright clear weather, and extends with a radius of about three times the shadow's diameter around the head alone. It is probably due to diffraction of light-waves, an explanation of which at length may be read in Glazebrook's "Optics" and in other text-books. But your correspondent omits the most extraordinary character of the phenomenon. It is a curious fact that any man can see the light around the shadow of his own head, but *never* about the shadow of another. Few people notice this halo, but when once pointed out to them, they tell me they frequently observe it. It is particularly clear when thrown across a valley from one ridge to another on the opposite side. I have puzzled over this spectral brightness for five years, and never found an explanation of the fact that no one can see anyone's halo but his own. I have delayed writing to NATURE until cause and effect could both be given, but they are not forthcoming.

Another curious appearance is a rainbow thrown by sunlight on black sound ice, probably due to polarization by crystals. On the one occasion when I saw it on a pond, I had no time to observe details. Has anyone seen the like? A. S. EVE.

Marlborough College.

Nesting Habit of the House Sparrow.

I SHOULD be glad to know if any of your correspondents have noticed a nesting habit of the house sparrow (*Passer domesticus*) which I have very frequently observed in this part of New Zealand. In many of the deep cuttings in our roads and in the cliffs upon our river-banks, where the formation is a light pumiceous sand, these birds are in the habit of burrowing holes similar to those of the sand-martin (*Hirundo riparia*). In some cases I have found these burrows by measurement to be as much as 6 feet in depth.

Can this be a recently acquired habit, and will it not have an influence upon the anatomical development of the bird?

Waihou, Auckland, N.Z., September 5. G. L. GRANT.

Sonorous Sands.

I NOTICE a letter from my friend Mr. A. R. Hunt in your issue of last week, and add a line to say that the sand which our common friend, the late Admiral Bedford, gave him was, *probably*, of my collecting.

I found that the sand in Studland Bay is sonorous, during a visit to Swanage, in 1869, and was, for many years, in such constant communication with the late Admiral Bedford, exchanging notes and specimens, that I think I must have given him the sonorous sand in question, though I cannot remember the circumstance.

Anyway, there is no doubt that the dry sands of Studland Bay are powerfully sonorous. Walking with my son and a young friend of his across the bay in July 1869, we all amused ourselves by kicking the musical dust before us, the two younger pairs of heels getting quite a volume of sound out of the performance. D. PIDGEON.

Holmwood, Putney Hill, October 6.

A Shell Collector's Difficulty.

IF Mr. Layard will discard "tightly-corked tubes" altogether, and keep his minute shells in open-ended sections of glass tube, lightly closed, at top and bottom, with cotton-wool, he will have no more trouble from "milky efflorescence," which will not form in presence of the "thorough draft" he will thus establish in his cabinet. D. PIDGEON.

Holmwood, Putney Hill, October 13.

Yorkshire Geological and Polytechnic Society.

IN accordance with a request made by the Council of the Yorkshire Geological and Polytechnic Society, I am compiling a history of the past fifty years' work of the Society, and including in it biographical notices of some of its principal members. Amongst the latter was the Rev. W. Thorp, who for several years held the office of Honorary Secretary, and took great interest in the Society. He was at one time vicar of Womersley, and afterwards removed to Misson. Unfortunately I can obtain no records of his life. Can any of your readers assist me? Any information will be gratefully received and duly acknowledged. I believe Mr. Thorp died about 1857.

Chevinedge, Halifax, October 15. JAMES W. DAVIS.

MODERN VIEWS OF ELECTRICITY.[1]

PART IV.—RADIATION.

XI.

WE have next to consider what happens when electrical waves encounter an obstacle.

Mechanism of Electric Radiation.

In forming a mental image of an electrical wave, we have to note that three distinct directions are involved. There is (1) the direction of propagation—the line of advance of the waves; (2) the direction of the electric displacements, at right angles to this; and (3) the direction of the magnetic axis, at right angles to each of the other two.

One may get a rough mechanical idea of the process of electrical radiation (at any rate in a plane) by means of the cog-wheel system already used in Part III. Imagine a series of elastic wheels, in one plane, all geared together, and let one of them be made to twist to and fro on its axis; from it, as centre, the disturbance will spread out in all directions, each wheel being made to oscillate similarly and to transmit its oscillation to the next. Looking at what is happening at a distance from the source, we shall see the pulses travelling from left to right; the electrical displacement, such as it is, being up and down; and the oscillating axes of the wheels being to and fro, or at right angles to the plane containing the wheels. The electric displacement is small, because the positive and negative wheels gearing into one another move almost equally, and accordingly there is the merest temporary balance of one above the other, due to the elastic "give" of the wheels. The magnetic oscillations, on the other hand, are all in one sense, the positive wheels rotating one way and the negative the other: all act together, and so the magnetic oscillation is a more conspicuous fact than the electric oscillation. Hence it is often spoken of as electro-magnetic radiation rather than as electric radiation. But the energy of the electrostatic strain is just as great as that of the electro-magnetic motion; in fact the energy alternates from the potential to the kinetic form, or *vice versâ*, at every quarter swing, just like every other case of vibration.

Prof. Fitzgerald, of Dublin, has devised a model of the ether, which by help of a little artificiality represents the two kinds of displacement—the electric and magnetic—very simply and clearly.

His wheels are separated from one another by a certain space, and are geared together by elastic bands. They thus turn all in one direction, and no mention need be made of positive and negative electricity as separate entities.

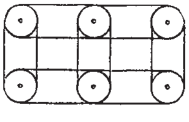

FIG. 48.—Fitzgerald's Ether Model. A set of brass wheels connected by common elastic bands. If the bands are taken off any region, it becomes a perfect conductor, into which disturbances cannot penetrate.

But, the wheels being massive, a rotatory disturbance given to one takes time to spread through the series, at a pace depending on the elasticity of the bands and the inertia of the wheels; and during the period of acceleration one side of every elastic is stretched, while the other side is relaxed and therefore thickened. This thickening of the elastics goes on in one direction, and corresponds to an electric displacement in that direction; the direction being perpendicular both to the direction of advance of the disturbance and to the axes of the wheels. A row of wheels corresponds to a section of a wave-front; the displacements of india-rubber and the rotating axes, *i.e.* the electric and the magnetic disturbances, both lie in the wave-front.

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[1] Continued from p. 419.

Clerk Maxwell's originally suggested representation was not unlike this.[1] It consisted of a series of massive wheels, connected together not by a series of elastic bands but by a row of elastic particles or "idle wheels." These particles represented electricity; their displacement during the period of acceleration corresponding to the one-sided thickening of the elastic bands in Fitzgerald's model.

I have proposed to contemplate a double series of wheels geared directly into one another, and representing positive and negative electricity respectively, because it seems to me that so many facts point to the existence of these two entities, and because then no distinction has to be drawn between one part of the medium which is ether, and another part which is electricity, but the whole is ether and the whole is also electricity; while, nevertheless, a much-needed distinction can be drawn between a motion of the ether as a whole, and a relative motion of its component parts—a distinction between forces able to move ether, *i.e.* to displace the centre of gravity of some finite portion of it, and forces which shear it and make its components slide past each other in opposite senses: these latter forces being truly electromotive.

If it be asked how the elasticity of the ether is to be explained, we must turn to the vortex sponge theory, suggested by Mr. Hicks[2] (principal of Firth College, Sheffield), and recently elaborated by Sir William Thomson.[3] But this is too complicated a matter to be suited for popular exposition just at present. It must suffice to indicate that the points here left unexplained are not necessarily at the present time unexplainable, but that the explanations have not yet been so completely worked out that an easy grasp can be obtained of them by simple mechanical illustrations and conceptions. At the same time, the general way in which motion is able to simulate the effects of elasticity will be found popularly illustrated in Sir William Thomson's article "Elasticity" in the "Encyclopædia Britannica"; and the fact that elastic rigidity of a solid can be produced by impressing motion on a homogeneous and otherwise structureless fluid must be regarded as one of the most striking among his many vital discoveries.

We have seen that to generate radiation an electrical oscillation is necessary and sufficient, and we have attended mainly to one kind of electric oscillation, viz. that which occurs in a condenser circuit when the distribution of its electricity is suddenly altered—as, for instance, by a discharge. But the condenser circuit need not be thrown into an obviously Leyden-jar form; one may have a charged cylinder with a static charge accumulated mainly at one end, and then suddenly released. The recoil of the charge is a true current, though a weak one; a certain amount of inertia is associated with it, and accordingly oscillations will go on, the charge surging from end to end of the cylinder like the water in a tilted bath suddenly levelled.

In a spherical or any other conductor, the like electric oscillations may go on; and the theory of these oscillations has been treated with great mathematical power both by Mr. Niven and by Prof. Lamb.[4]

Essentially, however, the phenomenon is not distinct from a Leyden jar or condenser circuit, for the ends of the cylinder have a certain capacity, and the cylinder has a certain self-induction; the difficulty of the problem may be said to consist in finding the values of these things for the given case. The period of an oscillation may still be written $2\pi\sqrt{(LS)}$; only, since L and S are both very small, the "frequency" of vibration is likely to be excessive. And when we come to the oscillation of an atomic charge the frequency may easily surpass the rate of vibration which can affect the eye. The damping out of such vibrations, if left to themselves, will be also a very rapid process, because the initial energy is but small.

But whether the charge oscillates in a stationary conductor, or whether a charged body vibrates as a whole, it equally constitutes an alternating current, and can equally well be treated as a source of radiation. Now, when we were considering the subject of electrolysis we were led to think of molecules as composed of two atoms or groups of atoms, each charged with equal quantities of opposite kinds of electricity. Under the influence of heat the components of the molecules are set in vibration like the prongs of a tuning-fork, the rate of vibration depending on and being characteristic of the constants of the particular molecule. The atoms being charged, however, their mechanical oscillation is necessarily accompanied by an electric oscillation, and so an electric radiation is excited and propagated outwards. These vibrations would appear to be often of the frequency suited to our retina, hence these vibrating atoms indirectly constitute our usual source of light. The "frequency" of the visible radiation can be examined and determined by optical means (some form of interference experiment, usually a diffraction grating), and hence many of the rates of vibration possible to the atoms of a given molecule under given circumstances become known, and this is the foundation of the science of spectroscopy.

It is possible that the long duration of some kinds of phosphorescence may be due to the atoms receiving indirectly some of the ethereal disturbance, and so prolonging it by their inertia, instead of leaving it to the far less inertia of the ether alone. It is possible also that the definite-emissivity of some fluorescent substances is due to periods of vibration proper to their atoms, which, being disturbed in an indirect way by receipt of radiation, re-emit the same radiation in a modified, and, as it were, laden manner.

To get some further idea concerning the way in which an oscillating charge or an oscillating charged body can propagate radiation, refer back to Fig. 39, Part III. (NATURE, vol. xxxvii. p. 346), and imagine the rack oscillating to and fro. It will produce rotatory oscillation in the wheels gearing into it, these again in the next, and so on. If the wheel-work were rigid, the propagation would go on at infinite speed to the most distant wheels, but if it be elastic then the pace of propagation depends on the elasticity and the density in a way we have already said enough about. The line of rack is the direction of electric oscillation, the axes of the wheels the direction of magnetic or rotatory oscillation, and at right angles to both these is the direction of advance of the waves. True, the diagram is not a space representation, it is a mere section, and a very crude suggestion of a mechanical analogy to what may be taking place.

The wheels being perfectly geared together and into the rack represent an insulator or dielectric: there is no slip or frictional dissipation of energy—in other words, there are no true electric currents. The electric oscillation is a mere displacement oscillation due to elasticity and temporary give of the elastic wheels, whereby during each era of acceleration they are thrown slightly into the state represented in Fig. 46 (vol. xxxvii. p. 367) as contrasted with Fig. 37 (*ibid.* p. 345).

Effects of encountering a New Medium.

Now contemplate an advancing system of waves, and picture their encounter with an obstacle; say, a medium of greater density, or less elasticity, or both. If the new medium is a perfect insulator, it must be considered as having its wheels thoroughly geared up both with themselves and with those of the initial medium, so that there is no slip or dissipation of energy at the surface. In this case none of the radiation will be lost: some will be reflected and some transmitted according to ordinary and well-known mechanical laws. The part transmitted will suddenly begin to travel at a slower pace, and hence if the incidence were oblique would pursue a somewhat different path. Also, at the edges of the obstacle, or at the boundary of any artificially limited portion of the wave, there will be certain effects due to spreading out and encroaching on parts of the medium not lying in the direct path. These refraction and diffraction effects are common to all possible kinds of wave propagation, and there is nothing specially necessary to be said concerning electrical radiation on these heads which is not to be found in any work on the corresponding parts of optics.

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[1] *Phil. Mag.*, April 1861.

[2] Brit. Assoc. Report, 1885, Aberdeen, p. 930.

[3] B.A. Report, 1887, Manchester, p. 486. Also *Phil. Mag.*, October 1887.

[4] Phil. Trans., 1881 and 1883. Also by Prof. J. J. Thomson, Math. Soc. Proc., April 1884.

Concerning the amount and direction of the reflected vibrations there is something to be said however, and that something very important; but it is no easy subject to tackle, and I fear must be left, so far as I am concerned, as a distinct, but perhaps subsequently-to-be-filled-up, gap.

If the gearing between the new medium and the old is imperfect, if, for instance, there were a layer of slippery wheels between them, representing a more or less conducting film, then some of the radiation would be dissipated at the surface, not all would be reflected and transmitted, and the film would get to a certain extent heated. By such a film the precise laws of reflection might be profoundly modified, as they would be also if the transition from one medium to another were gradual instead of abrupt. But all these things must remain for the present part of the unfilled gap.

Electric Radiation encountering a Conductor.

We will proceed now to the case of a *conducting* obstacle—that is, of waves encountering a medium whose electrical parts are connected, not by elasticity, but by friction. It is plain here that not only at the outer layer of such a medium, but at every subsequent layer, a certain amount of slip will occur during every era of acceleration, and hence that in penetrating a sufficient thickness of a medium endowed with any metallic conductivity the whole of the incident radiation must be either reflected or destroyed: none can be transmitted.

Refer back to Fig. 43 (vol. xxxvii. p. 347), and think of the rack in that figure as oscillating. Through the cog-wheels the disturbance spreads without loss, but at the outer layer of the conducting region A B C D a finite slip occurs, and a less amount of radiation penetrates to the next layer, E F G H, and so on. Some thickness or other, therefore, of a conducting substance must necessarily be impervious to electric radiation: that is, it must be opaque.

Conductivity is not the sole cause of opacity. It would not do to say that all opaque bodies must be conductors. But conductivity is a very efficient cause of opacity, and it is true to say that all conductors of electricity are necessarily opaque to light; understanding, of course, that the particular thickness of any homogeneous substance which can be considered as perfectly opaque must depend on its conductivity. It is a question of dissipation, and a minute but specifiable fraction of an original disturbance may be said to get through any obstacle. Practically, however, it is well known that a thin, though not the thinnest, film of metal is quite impervious to light.

When one says that conductivity is not the sole cause of opacity, one is thinking of opacity caused by heterogeneity. A confused mass of perfectly transparent substance may be quite opaque; witness foam, powdered glass, chalk, &c.

Hence, though a transparent body must indeed be an insulator, the converse is not necessarily true. An insulator need not necessarily be transparent. A homogeneous flawless insulator must, however, be transparent, just as a homogeneous and flawless opaque body must be a conductor.

These, then, are the simple connections between two such apparently distinct things as conducting power for electricity and opacity to light which Maxwell's theory points out; and it is possible to calculate the theoretical opacity of any given simply-constructed substance by knowing its specific electric conductivity.

Fate of the Radiation.

To understand what happens to radiation impinging on a conducting body it is most simple to proceed to the limiting case at once and consider a perfect conductor. In the case of a perfect conductor the wheels are connected not even by friction; they are not connected at all. Consequently the slip at the boundary of such a conductor is perfect, and there is no dissipation of energy accompanying it. The blank space in Fig. 38 (vol. xxxvii. p. 345), represented a perfectly conducting layer. Ethereal vibrations impinging on a perfect conductor practically arrive at an outer confine of their medium: beyond there is nothing capable of transmitting them; the outer wheels receive an impetus which they cannot get rid of in front, and which they therefore return back the way it came to those behind them with a reversal of phase: the radiation is totally reflected. It is like what happens when a sound-pulse reaches the open end of an organ-pipe; like what happens when sound tries to go from water to air; like the last of a row of connected balls along which a knock has been transmitted; and our massive elastic wheels are able to represent the reversal of phase and reflection quite properly.

The reflected pulses will be superposed upon and interfere with the direct pulses, and accordingly if the distances are properly adjusted we can have the familiar formation of fixed nodes and stationary waves.

The point of main interest, however, is to notice that a perfect conductor of electricity, if there were such a thing, would be utterly impervious to light: no light could penetrate its outer skin, it would all be reflected back: the substance would be a perfect reflector for ethereal waves of every size.

Thus with a perfect conductor, as with a perfect non-conductor, there is no dissipation. Radiation impinging on them is either all refracted or some reflected and some transmitted. It is the cases of intermediate conductivity which destroy some of the radiation and convert its ethereal vibrations into atomic vibrations, *i.e.* which convert it into heat.

The mode in which radiation or any other electrical disturbance diffuses with continual loss through an imperfect conductor can easily be appreciated by referring to Fig. 43 again. The successive lines of slip, A B C D, E F G H, &c., are successive layers of induced currents. An electromotive impulse loses itself in the production of these currents, which are successively formed deeper and deeper in the material according to laws of diffusion.

If the waves had impinged on one face of a slab, a certain fraction of them would emerge from the other face—a fraction depending on the thickness of the slab according to a logarithmic or geometrical-progression law of decrease. OLIVER J. LODGE.

(*To be continued.*)

PRESENT POSITION OF THE MANUFACTURE OF ALUMINIUM.

THE recent opening of new works for the manufacture of aluminium at Oldbury, near Birmingham, is distinctly an epoch in the history of this interesting metal.